ECOLOGY OF *HEXAGENIA* SP. AS INFLUENCED BY CENTRARCHID PREDATION

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PREFACE

This study was conducted to (1) estimate the standing crop of *Hexagenia* sp. under experimentally excluded fish predation and under control conditions involving fish predation, (2) measure the physicochemical conditions affecting the standing crop of *Hexagenia* sp. in the sample areas, and (3) provide information about the availability of fish food and its utilization by centrarchids.

Gratitude is extended to Dr. Roy W. Jones, my major advisor, for his guidance of the project and critical examination of the manuscript. Drs. Troy C. Dorris, Rudolph Miller, and L. Herbert Bruneau served on my advisory committee and also examined the manuscript. Special thanks are extended to Dr. David Bee for his aid in the statistical design and serving on the advisory committee. Thanks are extended to Dr. Harley W. Reno, R. E. Craven, Fred Rainwater, and Joseph Norton for their many discussions of the project.

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To my wife, Sonja, and to my parents, Owen and Mary Wade, I dedicate this manuscript.

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CHAPTER I

INTRODUCTION

Ecological knowledge is valuable in the management of fishes in impounded waters. Feeding habits of fishes are important to fishery biologists, hatchery managers, fish farmers, commercial minnow farmers, and commercial fishermen. Many researchers have reported mayfly nymphs and adults in the stomachs of fishes. Some of these workers are Forbes (1888a; 1888b), Needham and Betlen (1901), Needham (1920), Clemens and Bigelow (1922), Harkness (1923), Clemens, Dymond and Bigelow (1924), Clemens (1928), Adams and Hankinson (1928), Ricker (1930), Neave (1932), Deevey and Bishop (1941), Allen (1942), Leonard and Leonard (1949), Clemens (1952), Evans (1952), Bonn (1953), Hoopes (1960), and McComish (1967).

The objectives of this study were to (1) estimate the standing crop of *Hexagenia* sp. under experimentally excluded fish predation and under control conditions involving fish predation, (2) measure the physicochemical conditions affecting the standing crop of *Hexagenia* sp. in the sample areas, and (3) provide information about the availability of fish food and its utilization by centrarchids.

The experimental and control areas used in estimating population numbers and biomass of *Hexagenia* sp. were established at depths of 5, 10, and 15 ft. Physicochemical data were taken for 12 months (June, 1966, through May, 1967) with each benthic sample to test the effects that physicochemical conditions may have had on *Hexagenia* sp. population numbers and biomass.

CHAPTER II

DESCRIPTION OF THE LAKE

Boomer Lake (Fig. 1), constructed in 1925, is a 241-surface-acre reservoir in Payne County, Oklahoma. The lake is in R2E, T19N, S2 and R2E, T20N, S35 and had an original storage of 2,246.2 acre-feet with seven miles of shoreline. The area of the drainage basin is 5,843.2 acres (Eakin, 1936). The lake is used as a source of coolant for the Stillwater electric generation plant. The water is pumped from the lake, near the dam, tested, circulated through the cooling system of natural gas turbines, and returned to the lake by a flume. The water temperature is raised 10 F above that of the lake during the cooling operation. Maximum circulation is 40,000 gal/min.

Boomer Lake is located in the Permian Red Beds. The surface rocks of Payne County are basal Permian (Stillwater and Wellington) and upper Pennsylvanian (Koschmann, 1928). The drainage basin (Fig. 1) is characterized by low rolling hills and prairies, and edged with bottomland timber: American elm (*Ulmus americana*), eastern cottonwood (*Populus deltoides*), black willow (*Salix nigra*), and hackberry (*Celtis laevigata*). The understory consisted of shrubs, woody vines, herbaceous vegetation, legumes, small grains, sorghum, and other grasses. The prairie vegetation consisted of mixed stands of ravine-timber of blackjack (*Quercus marilandica*) and postoak (*Q. stellata*) and, in open grassland, little bluestem (*Andropogon scoparium*), big bluestem

(_A._ _gerardi_) and associated grasses.

The aquatic vegetation extended to a depth of 4 ft. The mean depth of the lake was 9.77 ft (Craven, 1968), with the deepest portion in the old creek channel near the dam (Fig. 2).

The fluctuation in transparency in Boomer Lake resulted from wind action on exposed clay banks, changes in plankton populations, and the addition of colloids from runoff water (Table I). Silt composed of bottom-set clays (Eakin, 1936) was extensively deposited from 1925 to 1966. The original creek channel was about 35 ft deep, but by 1966 had decreased to 25 ft. The primary sources of silt were from highway, road, and residential construction, and farming and land-fill projects. Many of the tributaries in the lake basin have been filled by silt (Fig. 4).

The surface area of Boomer Lake at elevation 910 ft was calculated as 246.3 acres (Eakin, 1936), but in 1966 the surface area was 241 acres, a loss of 5.3 acres attributable to a decreased shoreline that resulted from siltation in tributary arms. Eakin (1936) reported a deposition of 170.9 acre-feet of silt in a 10.25 - year period, an average of 16.7 acre-feet per year. If this figure were used to predict the loss, after 41 years, the lake should have lost 683.9 acre-feet of storage capacity. This loss did not occur, perhaps because of changes in land utilization.

The decrease in annual rainfall after 1940 would help explain the reduced siltation, presently calculated at 355.6 acre-feet for the 41-year period. The actual loss during the 41 years was 328.3 acre-feet less than the projected loss based on Eakin's average.

The average annual rainfall for the period, 1925-1936, was 34.4 inches or 2.4 inches above normal (approximately 32 inches). During the drought period from 1936 through 1939 the average annual rainfall was

2.8 inches below normal. This lower-than-normal rainfall, considered with a reduction in number of acres under cultivation, and terrace and pond construction, might account for reduced siltation. During the late 1930's and early 1940's, the lake was low, often with only 13 ft maximum depth. When the lake level was at elevation 895 ft, the earlier-deposited silt was shifted from the shallow, uncovered areas to deeper ones.

The lake has not been used as a municipal water supply since 1950. This change in use resulted in a more stable water level, approximately 2 ft below spillway level, elevation 910 ft.

The rate of sedimentation in Boomer Lake was studied by Harper (1941), but he did not compare depth contours before inundation with data taken later. Therefore, his data are not comparable to those discussed herein. Harper used a tubular sampling device and reported average depths of sediment in various areas without indicating sample locations (see Harper, 1941, Table I). Whereas Eakin (1936) indicated a loss of 170.9 acre-feet of storage capacity during a 10.25 - year period, Harper reported a loss of only 51.7 acre-feet during a 15 - year period. Eakin's data compared more favorably with the data presently reported, if considerations were given to annual rainfall and changes in the watershed.

During heavy rains the lake level was kept at approximately elevation 910 ft by use of discharge valves. The lower valve was used to release water, often heavily charged with suspended materials, from the deepest area of the lake. The runoff water entering the lake was usually cooler than the lake water and followed the deeper creek channel where much of the silt load was deposited. Great quantities of silt were deposited in the shallow water area because the littoral vegetation held and settled it out. The vegetated zone, in addition to the silt-holding action, contributed great quantities of organic debris.

Silt deposits, in the tributary arm, where the power plant flume returns discharge water to the lake, were reduced by the flushing action of the returning water (maximum 40,000 gal/min). The silt flushed from this area was deposited in the 15-ft depth where water velocity decreased (Fig. 4, transect A).

The shallow water (0-5 ft) of the north shore, near the creek entrance, had bottom materials with a median value of Phi 2 (sand). The prevailing south wind created waves that result in southward-flowing undertows, carrying smaller silt particles to deeper waters. This advance southward of the silt load had increased the shallow area in the north end of the lake.

Land fill projects and construction on the west shore have contributed much silt. Recent industrial construction on the east side of the lake has contributed additional silt, but the total effects have not been measured.

CHAPTER III

MATERIALS AND METHODS

To prevent fish predation of mayfly nymphs, three 7x7 ft exclosures were constructed of two-inch steel pipe frames covered by 1/4-inch hardware cloth and painted with water-proof spar varnish to inhibit deterioration (Fig. 3). The exclosures were placed in water depths of 5, 10 and 15 ft and extended one foot above spill-way level. Precautions were taken to exclude fish during installation of the exclosures.

A Galvanic-cell oxygen analyzer was used to measure dissolved oxygen near the exclosure bottoms and control areas. Surface and bottom water was taken with a Kemmerer water sampler and tested in a Hellige hydrogen-ion comparator. Methods for water testing were those of Welch (1948 and 1952) and Ruttner (1965). Water temperature was taken with a Telethermometer. A standard 20-centimeter Secchi disc was used to measure transparency.

Siltation data were compiled through comparison of a 1925 contour map (Black and Veatch, 1930) with the 1966 contour map. Bottom profiles along transects were drawn to scale using the 1925 and 1966 maps (Fig. 4).

Benthic samples were taken with an Ekman dredge (6x6 inches) from June, 1966, through May, 1967. Each month, at approximately weekly intervals, one sample was taken from each exclosure and control area of comparable depths.

Ekman dredge samples were taken from exclosures and control areas by use of an apparatus (boom) designed to prevent overlap in sampling (Fig. 5). Each Ekman sample was accompanied by a physicochemical water analysis. The Ekman dredge samples were sieved (0.42 mm openings) in the field, preserved in 10% formalin, and sieved again in the laboratory, sorted, and preserved in 50% isopropanol.

The mayfly nymphs were sorted according to head capsule size, the greatest distance between the outer margins of the eyes. These measurements ranged from 0.3 to 3.0 mm. Three samples of 10 individuals each from each head capsule size was oven dried for 24 hr at 100 C, cooled in dessicators to room temperature, and weighed in mg on an analytical balance. The mean weight ranged from 0.03 mg (0.3 mm group) to 6.50 mg (3.0 mm group).

Benthic organisms, other than mayfly nymphs, were identified, counted, and recorded.

Centrarchids were collected each month beginning in June, 1966, and continuing until May, 1967. The fishes were collected primarily in the 5-acre area near the exclosures. The data for each collection included: date, collection site, method of capture, water conditions, (e.g. turbidity, temperature, depth) and general weather conditions.

Four fish collecting devices or methods were used: seines, gill nets, shocker, and angling. Angling was most extensively used because each fish as caught could be weighed, measured, and the stomach removed and preserved in 10% formalin. The stomachs were later washed in water and placed in 50% isopropanol. The contents of the stomach from each fish were placed in distilled water, separated into species groups, each group counted, and the entire stomach contents measured volumetrically (in cubic centimeters) by distilled water displacement (see Table VI).

CHAPTER IV

ECOLOGY OF HEXAGENIA SP.

Standing Crop

Seasonal variations, commonly found in benthic communities, were exhibited by *Hexagenia* sp. in Boomer Lake. The population declined, because of emergence, in summer in all depths both inside and outside the exclosures (Fig. 6). The apparently uniform decline in all sample areas varied only in the magnitude of emergence from the three depths. The greatest summer decline of individuals occurred in the 15-ft depths which had an estimated loss of 50%. The loss to emergence in the 5- and 10-ft depths was 29% and 10% respectively. Numbers of individuals declined until late September, but began to increase during recruitment in October; similar observations were made in the Mississippi River populations by Fremling (1960a). The numbers of mayfly nymphs continued to increase until February. The apparent reduction in mayfly numbers in February may be explained as a withdrawal of nymphs into the burrows to escape adverse environmental conditions. *Hexagenia* sp. nymphs were observed by Fremling (1967) retreating into the burrows to escape high water temperatures (138 F) in a laboratory situation. Hunt (1953) reported burrows as deep as five inches, which would place the nymphs below the penetration of the Ekman dredge. The population in March was approximately the same as it was in January before the February reduction occurred. The reduction in numbers of nymphs taken in

February may have been due to mechanical rather than biological factors. If the dredge had been weighted, more nymphs might have been taken.

Seasonal predation by fishes on mayflies in the control areas was observed in the 5-, 10-, and 15-ft depths during summer months (Fig. 6; see also Tables VIII, IX, and X). The utilization of mayfly nymphs by fishes apparently was not restricted to any one depth but was more prevalent in the shallow waters in summer and deeper waters in winter. The analysis of variance for the effects of depth and treatment (exclosures) provided statistical evidence that the difference in populations in exclosure and control areas was not due just to random error but was also due to elimination of predation (Table II).

The mean numbers and biomass of mayfly nymphs in the 5-ft sample depths within and without exclosures had similar trends (Fig. 7). The numbers and biomass in the exclosures exceeded those of the control areas throughout the survey. A paucity of large nymphs in the February samples resulted in a sharp decline in weight, as indicated by the reduction in the curve for biomass. The reduction in weight per mayfly in the control area was not as severe as that of the exclosure because of the large numbers of shallow-burrowing smaller nymphs in the outside population. The population differences were explained by the presence of more intermediate- and large-sized nymphs in the exclosures (see Fig. 18). The control area fluctuations other than those explained by emergence and the February reduction were attributed to fish utilization. A reduction in mayfly numbers and biomass occurred during the period of emergence (Fig. 7, from June to September). During this period, heavy centrarchid utilization of subimagos and ovipositing female imagos occurred (see Tables VIII, IX, and X). During the October through December period centrarchids were feeding heavily on intermediate- and large-sized nymphs from the control area. The data obtained during the summer were misleading because emergence occurred in both the exclosure and control areas, with more reduction in the exclosure populations because of the greater number of larger nymphs. The populations in the 5-ft exclosure and control areas had greater differences in April and May because of the increased use of this depth by predators. The population biomass in the 5-ft control area during early spring did not increase as rapidly as those in the exclosure (Fig. 7).

The populations in the 10-ft areas were more stable and showed less reduction throughout the year than those in the other two depths, the greater difference being from July through January. During August, intermediate-sized nymphs comprised nearly 75% of the total 10-ft exclosure population (see Fig. 19). The intermediate-sized nymphs comprised approximately 25% of the December population, being reduced by the recruitment of many (over 50%) small nymphs. The populations of the exclosure and control area declined during emergence and the reduction in February were similar to those in the 5-ft depths. The mayfly biomass in the 10-ft exclosure was greater than that in the control area, indicating, and supported by observation, the presence of overwintering larger nymphs (Fig. 8). The populations of intermediate-sized (1.1 to 2.0 mm, head capsule) nymphs in the exclosure area were higher than in the control area where predation on intermediate-sized nymphs occurred. Fishes consumed large numbers of the intermediate-sized nymphs during the winter and early spring.

Population changes in the 15-ft depths were more pronounced in early winter and spring with increased numbers observed in the 15-ft exclosure samples (Fig. 9). The predation in early summer was not as great as that during the winter months and especially in late spring, when marked numerical differences in the two populations were apparent.

The populations were combined for the exclosure and control areas and mean values were calculated for each of the three depths (Fig. 10). The populations in the 10-ft depths were more stable than in the other sample depths. Combined analyses of variance for population numbers and biomass were calculated for the 12-month sampling period (Tables III and IV). The effects of depths, (5-, 10- and 15-ft) treatments (exclosures vs. control areas) and months (time) were statistically significant at the $\underline{F}$ 0.05 level. The effects of treatment on estimated population numbers and biomass were definitely significant. There was statistical evidence to conclude that the variation between treatments was above and beyond random error.

The populations were combined for the three depths and mean values were calculated for the exclosure and control areas. The differences in populations (exclosure minus control area) represented the predation by fishes exerted upon the mayfly. The predation on mayflies by fishes appeared to be constant most of the year, with slightly greater utilization occurring in the winter and early spring (Fig. 11).

The mean monthly biomass (dry wt) adjusted for combined effects of depths and treatments indicated more stability in the control areas than in the exclosures (Fig. 12). The biomass in the control areas (all depths) was composed of smaller nymphs with larger individuals having been eaten by fishes. The biomass in the exclosures during winter fluctuated more than in the control areas because of recruitment and the early winter and spring with increased numbers observed in the 15-ft exclosure samples (Fig. 9). The predation in early summer was not as great as that during the winter months and especially in late spring, when marked numerical differences in the two populations were apparent.

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The more stable biomass in the 10-ft depths was evidenced by the mean monthly biomass (dry wt), adjusted for combined effects of treatment for all sample depths (Fig. 13). The biomass in the 15-ft depths exceeded that in the 10-ft depths in June, 1966, and April and May, 1967. The population biomass, but not the population numbers, in the 5-ft depth exceeded that of the 15-ft depth during March, 1967 (Figs. 10 and 13).

The mean monthly dry weight for individual mayflies in combined areas and depths was highest prior to emergence and lowest in midwinter. The recruitment of small nymphs, beginning in October and extending through December, reduced the mean weight per individual and produced the midwinter decline in weight (Fig. 14). Predation by fishes on larger nymphs in the control areas during winter months was reflected by the reduced weight per nymph.

The mean monthly dry weight per nymph from the 5-ft exclosure and control areas declined during the period of emergence. The mayflies that emerged were not all lost from the basin, but were used by fishes (see Tables VIII, IX, and X; Fig. 15). The lower mean weight per nymph (Fig. 15) in December was explained by the presence in the samples of great numbers of small nymphs from summer recruitment. A wide variation in weight per nymph indicated, in part, fish predation in early fall. The differences in mean weight per nymph in late winter and early spring were attributed to three factors (1) reduced predation in shallow waters in winter, (2) the larger nymphs in the exclosure may have been in deeper burrows, and (3) more active feeding by nymphs resulted in weight increase.

The mean weight per nymph in the 10-ft depths did not show the rapid decrease in summer months, but a gradual decline until January (Fig. 16).

The mean weight per nymph in the 15-ft depths was more variable than those of the shallower depths (Fig. 17). The decline in weight per mayfly in the exclosure in September was attributed to late emergence in deeper water. This apparent decline in weight per nymph was not observed in the control area because predation nearly eliminated the larger nymphs (see Table VIII, IX and X). The curves for mayfly mean weight converged in March, April and May because of the slower warming of the deeper waters and a prolonged period of inactivity of over-wintering nymphs. The movement of fish to shallower waters in spring may have reduced the predation in the 15-ft depth.

Percent contributions by different sizes of mayfly nymphs to the standing crop in the three depths were used in predicting trends of predation and fluctuations in biomass (Figs. 18, 19 and 20).

Contributions by smaller nymphs (head capsule, 0.1 - 1.0 mm) to the exclosure populations in the 5-ft depth were below 25% in the summer, 75% in the winter, and below 50% in the spring (Fig. 18). Because of increased mayfly growth in April and May, the smaller nymphs were in the intermediate-sized (1.1 - 2.0 mm) group. The progression of individuals in the spring from one size group to another was evident in all depths. The intermediate-sized nymphs in the control area were apparently absent in the samples in October until growth of smaller nymphs placed them into the intermediate-sized group. The observed absence in the control area of larger (2.1 - 3.0 mm) nymphs from August until April may be explained by slower growth during winter and predation by fishes on larger nymphs. Larger nymphs were seldom taken from the exclosure areas during February since they may have withdrawn deeper into burrows. Fish stomachs regularly contained larger-sized nymphs during winter and early spring.

The populations during summer in the 10-ft depths were somewhat different in the numbers of intermediate-sized nymphs from those in the 5-ft depths. Larger nymphs were present in the exclosure populations throughout the sample period but were absent from the samples in the control area from June, 1966, until March, 1967.

The populations in the 15-ft depths were composed primarily of intermediate- and large-sized nymphs during summer months, of smaller nymphs (after recruitment) in fall, winter and early spring, and of intermediate and larger nymphs in late spring. The predation by fishes on intermediate-sized nymphs in May caused an increase in percent contribution of smaller nymphs, but not an increase in numbers.

Hexagenia sp. maximum monthly mean abundance occurred in May with $237/m^2$ in the control areas and $421/m^2$ inside the exclosures. There were higher estimated weekly exclosure populations, e.g. sample 1 in May ($509/m^2$) but the maximum May weekly sample was not accompanied by other high weekly population numbers. The minimum monthly mean mayfly abundance occurred in September with $67/m^2$ outside and $202/m^2$ inside the exclosures.

Statistical Analyses

The effects of treatment (exclosures) were significant at the 0.01 level in the analyses of variance throughout the sample period (Table II). The calculated difference in the two treatments (exclosures minus control areas) was at times significantly greater than the observed population in the control areas. The predation by fishes during some sample periods was over 50% of the existing standing crop (see Table XIII "forage ratios").

The effects of depths were statistically significant at the 0.05 level most of the year but did not exhibit the magnitude of significance of treatments ($P<0.0005$ indicates that the probability of obtaining a calculated *F* as large or larger than that which was observed is less than 0.0005 when the hypothesis of equality is true). Interactions of depths and treatments were statistically significant ($P<0.005$) part of the year but did not approach the magnitude exhibited by the effects of either depths ($P<0.0005$) or treatments ($P<0.0005$).

Physicochemical conditions were taken with each benthic sample, and their effects were tested by use of a stepwise regression procedure. None was found to be statistically significant at the 0.05 level, but the effects of bottom water temperatures during mayfly emergence approached meaningful values at the 0.10 level.

The combined monthly analyses of standing crop of *Hexagenia* sp. were affected by treatments with a population calculated *F* of 608.2 and biomass 880.7. The probability of observing an *F* value as large as the above was less than 0.0005. A calculated *F* as large as those above added statistical evidence to the statement that the large standing crop inside the exclosures could not be attributed just to random error but also to the elimination of predation (Tables II, III and IV).

CHAPTER V

FISHES OF THE BOOMER CREEK BASIN

There are no published lists of fishes prior to consturction of Boomer Lake dam in May, 1925. The earliest published record was that of Moore and Mizelle (1939). The area was sampled by Cross (1950) and by Wade and Craven (1965) (Table V).

List of Fishes of Boomer Lake

The following list includes species that were present in Boomer Lake from June, 1966, through May, 1967.

CLUPEIDAE -- Herring and shad

1. _Dorosoma cepedianum_ (LeSueur). Gizzard shad

CATOSTOMIDAE -- Suckers

2. _Carpiodes carpio_ (Rafinesque). River carpsucker

CYPRINIDAE -- Minnows

3. _Cyprinus carpio_ (Linneaus). Carp
4. _Carassius auratus_ (Linneaus). Goldfish
5. _Notemigonus crysoleucas_ (Mitchell). Golden shiner
6. _Notropis lutrensis_ (Baird and Girard). Red shiner
7. _Pimephales promelas_ (Rafinesque). Fathead minnow

ICTALURIDAE -- Catfishes

8. _Ictalurus punctatus_ (Rafinesque). Channel catfish
9. _Ictalurus melas_ (Rafinesque). Black bullhead

10. *Plyodictis olivaris* (Rafinesque). Flathead catfish

ATHERINIDAE -- Silversides

11. *Menidia audens* (Hay). Mississippi silversides

SERRANIDAE -- Sea basses

12. *Roccus chrysops* (Rafinesque). White bass

CENTRARCHIDAE -- Sunfishes

13. *Micropterus salmoides* (Lacépède). Largemouth bass

14. *Lepomis cyanellus* (Rafinesque). Green sunfish

15. *Lepomis humilis* (Girard). Orangespotted sunfish

16. *Lepomis megalotis* (Rafinesque). Longear sunfish

17. *Lepomis macrochirus* (Rafinesque). Bluegill

18. *Lepomis microlophus* (Gunther). Redear sunfish

19. *Pomoxis annularis* (Rafinesque). White crappie

20. *Pomoxis nigromaculatus* (LeSueur). Black crappie

Introduced Species

Carassius auratus. Goldfish. Two large specimens, probably escapees from a fish pond or introduced from a baitbucket,were collected.

Pimephales promelas. Fathead minnow. This minnow was taken occasionally in the lake and was replenished from baitbuckets of fishermen. Although this species is indigenous to Oklahoma, the Boomer Lake population may be in part derived from Minnesota, as bait dealers purchase stock from that state.

Hybognathus placitus (Girard). Plains minnow. This minnow is abundant in the Cimarron River and known to occur in the Stillwater Creek Basin, but was scarce in Boomer Lake.

Pylodictis olivaris. The flathead catfish was found in the

Boomer Creek area and in the lake until the rotenone application of 1954. In 1952, the state sport-fishing record flathead (95 lb.) was taken from Boomer Lake. This species was reintroduced on July 13, 1967.

Menidia audens. Mississippi silversides. This fish was introduced into Boomer Lake in 1961 (Sisk and Stephens, 1964). It has increased in abundance to rival the gizzard shad, and furnished forage for sport fishes.

Roccus chrysops. White bass. White bass in small numbers have been introduced by fishermen. One specimen (3½ lb.) was taken on hook and line. The absence of young or juvenile fish indicated the lack of spawning in the lake.

Hybrids

The most abundant sunfish hybrid in Boomer Lake was *Lepomis microlophus* x *L. cyanellus*. *L. microlophus* was the more abundant of the two parent species. Other, but less numerous hybrids were: *L. macrochirus* x *L. cyanellus*, *L. macrochirus* x *L. microlophus*, and *L. macrochirus* x *L. megalotis*.

Items Consumed by Fishes of Boomer Lake

Hexagenia sp. was found in 94.7% of the white crappie stomachs and comprised 52.5% of the total food volume (see Table VII and VIII). Crawley (1954) reported from Boomer Lake a total of 390 *Hexagenia* sp. taken from 259 white crappie stomachs; in this study 8,411 mayflies were taken from 674 white crappie stomachs. The monthly mean volume of stomach contents, in cubic centimeters, for each species of fish is presented in Table VI; the data for white crappie are compared with those of Crawley (1954).

During the summer months when mayflies rose to the water surface to transform into subimagos, or returned as female imagos to deposit eggs, they were consumed by bluegill. This utilization of larger mayflies during summer months is shown in Table IX in contrast to the use of smaller nymphs in the winter months, October and November. Mayfly nymphs comprised 10.5% of total occurrence and 2.5% of total food volume in bluegill stomachs (Table VII). Hunt, 1953, reported the use of Hexagenia limbata by bluegill at a much higher ratio (40.7% occurrence and 50.5% of the total food volume).

Hexagenia nymphs were absent from the small sample (75) of green sunfish stomachs, but were found in 36 (19.2%) redear sunfish stomachs and comprised 5.0% of the total food volume (Table VII and X). Mayfly nymphs were consumed in small numbers by young largemouth bass. Black crappie contained a total of 68 nymphs comprising 27% of the total food consumed (Table VII).

Forage fishes - The forage fish population has expanded due to earlier absence of predatory fishes and the introduction of additional species. The predatory fish reduction was accomplished by rotenone poisoning of Boomer Lake in 1954. The poisoning was an effort to control the overpopulation of crappie and to remove rough fishes.

Menidia audens (Mississippi silversides) was introduced into Boomer Lake in 1961 (Sisk and Stevens, 1964) and has now increased to a place of great importance, being utilized by largemouth bass, channel catfish, and crappie. The gizzard shad (Dorosoma cepedianum) population has also increased possibly due to the above-mentioned lack of predatory fishes. The unusable large gizzard shad have become a major portion of the fish population. Shad were found in stomachs of large white crappie, largemouth bass, and channel catfish; e.g., a 6-lb. 4 oz. bass contained an 8.9-inch shad. Gizzard shad, silversides and small sunfishes were used primarily during the winter months. Fish remains constituted 73% of the total food volume of black crappie and 33% of the volume for largemouth bass. Fish remains were also found in bluegill, white crappie, and green sunfish (Table XI).

Aquatic insects - The use of aquatic insects was extensive by seven species of centrarchids of Boomer Lake. Caddisflies were one of the earliest groups to emerge, possibly because of the warmer water in the flume area where hatches were recorded in February, 1967. This contrasts with Fremling's (1960b) report of earliest emergence of caddisflies in the Mississippi River during mid-June. Caddisflies, during periods of emergence in Boomer Lake, constituted a large portion of aquatic insects in stomachs of bluegill, white crappie, redear, and longear. Extensive surface feeding by fishes was observed during February.

Other groups of aquatic insects represented in the stomach contents were Neuroptera, Coleoptera, Odonata, and Diptera.

Terrestrial insects - Insects comprised a large portion of the total volume of food found in the fish samples studied (Table XI). Six species of centrarchids sampled contained terrestrial insects. The longear and redear sunfishes were dependent on these insects during the summer months. The orders represented by their presence in stomach analyses were: Orthoptera, Dermaptera, Hemiptera, Homoptera, Neuroptera, Lepidoptera, Diptera, Coleoptera, and Hymenoptera.

Crustacea - Utilization of Crustacea by fishes appeared to be restricted to small crayfish and smaller members of the class; the pelagic (Hyalella azteca) was most frequently used. Copepoda, Branchiopoda (Cladocera), and Ostracoda were frequently found in the stomachs, but no plankton population information was obtained. Crawley (1954) reported Cladocera as one of the primary food items of white crappie (21.7%). In my investigation they were placed in the larger group Crustacea and comprised a significant numerical portion of the food, but much less volumetrically. Crayfish comprised a large portion of the total food volume of largemouth bass during the late winter and early spring months, but were not found as frequently during summer and fall months, when forage fishes and the young-of-year centrarchids were more frequently used. Other Arthropods represented in the stomach contents were Amphipoda and Decapoda.

Mollusca - Molluscs (snails, fingernail clams, and mussels) were all grouped under the phylum heading (Table XII). Fingernail clams and snails were frequently found in the stomachs of bluegill and redear. Fingernail clams appeared in greater volume than any other food item (54.0% of the total volume) in stomachs of redear sunfish (Table XIII). Three bluegills examined had their hind-guts impacted with Physa shells.

Bryozoa -Bryozoans were abundant in association with large populations of aquatic insects in the shallow water and flume area. The sunfishes consumed large quantities of aquatic insects and, since bryozoans were also taken by the fishes, it may be that the latter were taken incidentally with aquatic insects. Bryozoans and portions of their tentacles, lophophores, and commonly, in smaller fishes, statoblasts were found in fishes stomachs.

Vegetation - The large volume of vegetation consumed by Boomer

Lake fishes possibly can be explained by the abundance of macroinvertebrates associated with vegetation. The close association of macroinvertebrates with vegetation was stated by Buscemi (1961), in his discussion of Parvin Lake populations, where he found ten species of organisms living in the matrix of Elodea (= Anacharis) canadensis. The vegetation found in Boomer Lake fishes was leafy material of pond weed Potamogeton, large volumes of the alga (Chara), and occasional leaves of Najas quadalupensis. Algae are included under the heading of vegetation herein and comprised a major portion of the stomach contents of four species of fishes (Table XI). Not all, but a major portion, of the material listed under vegetation was algae. The Oogonium of Ulotrichales, filamentous algae, with its enclosing sheath of cells was reported as spermocarp by Crawley (1954). Spermocarp comprised 0.2% of the total volume in Crawley's investigation and 0.5% in my study. Crawley found that algae comprised 31.1% of the total stomach contents of white crappie, but for the same species I found only 6.0%.

Miscellaneous items - The only listing of miscellaneous items in my study was for the green sunfish which included: duck feathers, a small adhesive bandage, and invertebrate eggs. According to Crawley (1954), invertebrate eggs comprised a large portion of the food of white crappie, with a total of 138,106 invertebrate eggs from Boomer Lake fishes. This was not true in my investigation and only small numbers (0.01% by volume) of invertebrate eggs were recorded.

The position occupied by Hexagenia nymphs in the diet of bluegill, white crappie, redear sunfish, black crappie and largemouth bass is presented in Table XIII. In order to estimate the extent of predation of these fishes on the nymphs, it was necessary to compare the nymphs position in the macroscopic bottom fauna with that of its percentage food used by various fishes. This relationship, termed the "forage ratio" (Ball, 1948; Hess and Swartz, 1940) was determined by the exclusion of Pisces, Entomostraca, terrestrial insects, aquatic nymphs other than Hexagenia, Mollusca, Bryozoa and vegetation from the food volume and recalculating the data on a basis of those fish foods which were obtained by quantitative bottom sampling (Table XIV). Percentage values for the number of Hexagenia nymphs in bottom samples, in fish stomachs, and the "forage ratio" for the fishes collected, are presented in Table XIII. The bluegill and redear sunfish utilization of nymphs and adults was evident during late summer and early fall. The increased utilization was during times of emergence, with larger mayflies predominating in stomach contents.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The objectives of this study were to (1) estimate the standing crop of *Hexagenia* sp. under experimentally excluded fish predation and under control conditions involving fish predation, (2) measure the physicochemical conditions affecting the standing crop of *Hexagenia* sp. in the sample areas, and (3) provide information about the availability of fish food and its utilization by centrarchids.

The only environmental condition that produced an effect on the mayfly standing crop was the bottom water temperature, accompanied by other conditions that may have indrectly influenced the mayfly standing crop but were not statistically important per se. Silt may have covered the mayfly burrows during heavy rains and caused the nymphs to leave or reconstruct burrows. The remaining physicochemical conditions were not considered statistically significant as influencing the mayfly numbers or biomass.

Standing crops were estimated by using Ekman dredge samples, taken from June, 1966, through May, 1967, from exclosures (excluding fish predation) and control areas (involving fish predation) at depths of 5, 10, and 15 ft.

Seasonal benthic population fluctuations were apparent. Other fluctuations in populations were attributed to predation and natural mortality. The exclosure standing crops exceeded those of the control areas in all depths throughout the year. The mathematical difference between the standing crop in the exclosure, and control areas at times exceeded the estimated standing crops in the control areas. The estimated standing crop of Hexagenia sp. in the control areas was reduced over 50% at times by predation.

Stomach analyses of eight species (2,000 fishes) of centrarchids were made. White crappie appeared to be the greatest consumer of Hexagenia sp. with 94.7% containing mayflies. Other consumers of mayflies were black crappie (50%), redear sunfish (19.2%), bluegill (10.5%), and largemouth bass (6.3%).

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APPENDIX A

TABLE I

MONTHLY MEAN PHYSICOCHEMICAL CONDITIONS

	Temperature near bottom	DO near bottom	pH near bottom	Trans- parency inches	Rain- fall* inches	Lake level* feet
1966						
June	81.50	7.00	8.2	11.50	2.59	26.00
July	84.66	5.32	8.3	10.50	7.92	28.20
August	82.08	6.53	8.2	10.75	2.73	27.40
September	73.17	7.15	8.3	14.75	1.36	27.20
October	57.17	7.85	8.3	22.00	0.40	26.80
November	49.31	6.54	8.3	30.75	0.19	26.40
December	41.50	8.25	8.3	34.50	1.72	26.30
1967						
January	38.50	11.50	8.4	13.50	2.55	26.50
February	40.81	12.21	8.4	23.25	0.59	26.40
March	47.48	8.32	8.3	25.08	2.06	26.30
April	62.69	8.00	8.2	18.50	3.56	27.00
May	78.21	6.82	8.2	7.00	7.81	27.90

*Data provided by the generation plant superintendent. Other data were taken with each benthic collection.

TABLE II

MONTHLY CALCULATED *F* VALUES AND PROBABILITY STATEMENTS FOR STANDING CROP OF *HEXAGENIA* SP.

	Source of Variance				
	Replications	Main Effects		Interaction	Error
	R (days)	A (depths)	B (treatments)	AB	
degrees freedom	3	2	1	2	15
1966					
June					
ms (mean squared)	11,143.1	48,790.4	108,272.7	6,158.0	6,216.7
F (calculated)	1.79	7.85	17.42	0.99	
P (probability)	<0.25	<0.005	<0.001	<0.50	
July					
ms	10,847.7	28,948.6	90,123.3	14,643.9	1,693.5
F	6.38	17.09	53.21	8.64	
P	<0.01	<0.0005	<0.0005	<0.005	
August					
ms	1,953.4	28,091.3	78,112.9	16,006.2	3,015.8
F	0.65	9.31	25.90	5.30	
P	<0.75	<0.005	<0.0005	<0.025	
September					
ms	10,962.6	18,338.9	108,272.7	6,158.0	2,354.9
F	4.65	7.80	45.97	2.61	
P	<0.025	<0.005	<0.0005	<0.25	
October					
ms	2,093.9	19,834.7	140,117.6	9,146.6	2,783.8
F	0.75	7.12	50.33	3.28	
P	<0.975	<0.01	<0.0005	<0.01	
November					
ms	5,540.8	8,238.9	152,681.4	7,426.8	1,444.5
F	3.83	5.70	105.69	5.14	
P	<0.05	<0.025	<0.0005	<0.025	
December					
ms	1,638.0	9,887.8	142,835.5	6,117.2	2,649.6
F	0.61	3.73	53.90	2.30	
P	<0.75	<0.05	<0.0005	<0.25	

TABLE II (Continued)

	Source of Variance				
	Replications	Main Effects		Interaction	Error
	R (days)	A (depths)	B (treatments)	AB	
degrees freedom	3	2	1	2	15
1967					
January					
ms	3,490.7	4,330.9	152,681.4	879.7	1,582.4
F	2.20	2.74	96.49	0.56	
P	<0.25	<0.25	<0.0005	<0.95	
February					
ms	7,037.7	2,047.0	119,370.6	4,618.5	1,042.1
F	6.17	1.96	114.55	4.43	
P	<0.01	<0.25	<0.0005	<0.05	
March					
ms	180.5	473.7	113,754.0	473.7	356.4
F	0.50	1.33	319.18	1.33	
P	<0.75	<0.50	<0.0005	<0.50	
April					
ms	2,030.1	8,391.1	219,861.2	7,308.4	1,394.0
F	1.45	6.02	157.72	5.24	
P	<0.50	<0.025	<0.0005	<0.025	
May					
ms	1,213.1	2,248.8	204,564.5	8,414.8	2,057.2
F	0.58	1.09	99.44	4.09	
P	<0.75	<0.50	<0.0005	<0.05	

TABLE III

COMBINED MONTHLY ANALYSIS OF VARIANCE OF POPULATIONS NUMBERS OF *HEXAGENIA* SP.

source of variance	degrees of freedom	mean square	calculated F	probability
Replications				
R (days)	3	17,217.7	6.6	$P < 0.0005$
Main Effects				
A (depths)	2	95,875.8	36.5	$P < 0.0005$
B (treatments)	1	1,595,398.2	608.2	$P < 0.0005$
C (months)	11	129,665.8	49.4	$P < 0.0005$
Two-factor Interactions				
AB	2	44,252.5	16.9	$P < 0.0005$
AC	22	9,453.3	3.6	$P < 0.0005$
BC	11	3,204.6	1.2	$0.25 < P < 0.50$
Three-factor Interactions				
ABC	22	3,918.1	1.5	$0.05 < P < 0.10$
Error	213	2,623.2		

HYPOTHESES

Null hypotheses for main effects:

Factor A: $a_1 = a_0$

Factor B: $b_1 = b_0$

Factor C: $c_1 = c_0$

Null hypotheses for two-factor interactions:

AB interaction

$$(ab)_{11} + (ab)_{00} = (ab)_{10} + (ab)_{01}$$

AC interaction

$$(ac)_{11} + (ac)_{00} = (ac)_{10} + (ac)_{01}$$

BC interaction

$$(bc)_{11} + (bc)_{00} = (bc)_{10} + (bc)_{01}$$

Null hypotheses for three-factor interaction:

ABC interaction

$$(abc)_{111}+(abc)_{100}+(abc)_{010}+(abc)_{001} = (abc)_{110}+(abc)_{101}+(abc)_{011}+(abc)_{000}$$

TABLE IV

COMBINED MONTHLY ANALYSIS OF VARIANCE OF POPULATION BIOMASS OF *HEXAGENIA* SP.

source of variance	degrees of freedom	mean square	calculated F	probability
Replications				
R (days)	3	25,982.6	5.0	0.001<P<0.005
Main Effects				
A (depths)	2	379,870.4	73.4	P<0.0005
B (treatments)	1	4,558,203.3	880.7	P<0.0005
C (months)	11	243,509.7	47.1	P<0.0005
Two-factor Interactions				
AB	2	180,602.0	34.9	P<0.0005
AC	22	30,152.1	5.8	P<0.0005
BC	11	22,344.7	4.3	P<0.0005
Three-factor Interactions				
ABC	22	9,100.5	1.8	0.01<P<0.05
Error	213	5,175.6		

Hypotheses for biomass are the same as those for population.

TABLE V

THE FISHES* OF BOOMER CREEK

SPECIES	MM** (1939)	C† (1950)	W††(1965)
Dorosoma cepedianum		17	6
Carpiodes carpio		10	7
Cyprinus carpio		18	
Notemigonus crysoleucas		6	6
Notropis lutrensis	4	1	2
Hybognathus placitus			6
Pimephales promelas		7	3
Pimephales vigilax		8	
Pimephales notatus		15	
Campostoma anomalum		15	
Ictalurus punctatus		14	
Ictalurus melas	1	11	5
Fundulus notatus	6	5	
Gambusia affinis			1
Micropterus salmoides	3	15	
Chaenobryttus gulosus		18	
Lepomis cyanellus	2	12	4
Lepomis humilis		4	
Lepomis megalotis		12	7
Lepomis macrochirus	1	2	
Lepomis microlophus		16	7
Pomoxis annularis	4	3	
Pomoxis nigromaculatus	5	9	

* Ranked in decreasing order of abundance
** Collections of Moore and Mizelle (1939)
† Collections of Cross (1950)
†† Collections of Wade and Craven (1965)

TABLE VI

MEAN VOLUME* OF STOMACH CONTENTS FROM FISHES FROM BOOMER LAKE

Species	June '66	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan. '67	Feb.	Mar.	Apr.	May
Bluegill	0.18	0.20	0.19	0.17	0.15	0.10	0.07	0.08	0.11	0.16	0.14	0.17
White crappie	0.15	0.10	0.12	0.14	0.10	0.09	0.18	0.14	0.19	0.32	0.26	0.23
**	0.09	0.12	0.10	0.31	0.11	0.08	0.05	0.08	0.10	0.15	0.29	0.18
Green sunfish	0.83	0.38	0.26	----	----	----	----	----	0.19	----	----	----
Redear sunfish	0.13	0.09	0.10	0.11	0.10	----	----	----	0.08	----	----	----

* Volume expressed in cubic centimeters

** White crappie (see Crawley, 1954)

TABLE VII

CENTRARCHID UTILIZATION OF HEXAGENIA SP.

	FISH SAMPLED				MAYFLY NYMPHS			
SPECIES	TOTAL	EMPTY	PERCENT	CONTAINING HEXAGENIA	PERCENT	TOTAL	AVERAGE /FISH	PERCENT OF TOTAL VOLUME
White crappie	882	170	19.3	674	94.7	8,411	12.47	52.5
Bluegill	794	232	29.2	59	10.5	166	2.81	2.5
Green sunfish	75	50	66.7	0	-	-	-	-
Redear sunfish	188	69	36.7	36	19.2	117	3.30	5.0
Longear sunfish	12	0	-	0	-	-	-	-
Largemouth bass	32	20	62.5	2	6.3	10	5.0	0.8
Black crappie	8	0	-	4	50.0	68	17.0	27.0
Orangespotted sunfish	9	9	100.0	-	-	-	-	-

TABLE VII

CENTRARCHID UTILIZATION OF HEXAGENIA SP.

	FISH SAMPLED				MAYFLY	NYMPHS		
SPECIES	TOTAL	EMPTY	PERCENT	CONTAINING HEXAGENIA	PERCENT	TOTAL	AVERAGE /FISH	PERCENT OF TOTAL VOLUME
White crappie	882	170	19.3	674	94.7	8,411	12.47	52.5
Bluegill	794	232	29.2	59	10.5	166	2.81	2.5
Green sunfish	75	50	66.7	0	-	-	-	-
Redear sunfish	188	69	36.7	36	19.2	117	3.30	5.0
Longear sunfish	12	0	-	0	-	-	-	-
Largemouth bass	32	20	62.5	2	6.3	10	5.0	0.8
Black crappie	8	0	-	4	50.0	68	17.0	27.0
Orangespotted sunfish	9	9	100.0	-	-	-	-	-

TABLE VIII

OCCURRENCE OF HEXAGENIA SP. IN STOMACHS OF WHITE CRAPPIE

	number of stomachs containing nymphs	number of nymphs in stomachs			percent of total containing nymphs	nymph size	
		ave.	max.	total		range	ave.
1966							
June	8	11.5	13	92	40.0	0.8-2.4	1.9
July	20	10.0	12	200	71.4	0.8-2.8	1.6
August	30	11.0	12	330	100.0	0.8-2.8	1.7
September	8	14.0	18	112	100.0	0.8-1.4	1.2
October	30	12.0	13	360	100.0	0.8-1.4	1.3
November	4	11.0	11	44	100.0	0.8-1.6	1.1
December	160	10.0	13	1,600	93.0	0.8-2.4	1.6
1967							
January	124	12.0	13	1,488	73.9	0.8-2.3	1.6
February	58	15.5	18	899	70.0	0.8-2.4	1.6
March	68	15.0	17	1,020	100.0	0.7-1.8	1.2
April	124	14.5	16	1,798	93.9	0.7-2.4	1.6
May	36	13.0	15	468	90.0	0.7-2.8	1.5

TABLE IX

OCCURENCE OF HEXAGENIA NYMPHS IN STOMACHS OF BLUEGILL FROM BOOMER LAKE

	number of stomachs containing nymphs	number of nymphs in stomachs			percent of total containing nymphs	nymph size	
		average	maximum	total		range	average
1966							
June	8	5.0	9	40	40.0	1.8-2.8	2.2
July	10	2.4	6	24	50.0	1.8-2.8	2.5
August	21	3.0	7	63	70.0	1.8-2.8	2.0
September	6	2.5	4	15	18.8	1.8-2.8	2.0
October	6	2.0	3	12	4.8	1.0-1.8	1.5
November	8	1.5	2	12	5.7	0.8-1.7	1.5

TABLE X

OCCURRENCE OF HEXAGENIA SP. IN STOMACHS OF SUNFISH, OTHER THAN BLUEGILL AND WHITE CRAPPIE FROM BOOMER LAKE

	number of stomachs containing nymphs	number of nymphs in stomachs			percent of total containing nymphs	nymph size	
		average	maximum	total		range	average
1966							
June							
Redear	6	4.0	4	24	33.3	0.8-2.8	1.8
July							
Redear	18	2.5	3	45	46.2	0.8-2.8	1.6
August							
Redear	6	2.0	2	12	42.9	0.8-2.6	1.7
September							
Redear	3	6.0	7	18	25.0	0.8-1.8	1.6
October							
Redear	3	6.0	7	18	9.1	0.8-1.4	1.2
1967							
March							
Black crappie	4	17.0	17	68	50.0	0.8-1.5	1.1
April							
Largemouth bass	2	5.0	5	10	33.3	0.7-1.8	1.4

TABLE XI

ITEMS* CONSUMED BY BOOMER LAKE FISHES

Species	Fish remains	Aquatic Nymphs	Terrestrial Insects	Crustacea	Mollusca	Bryozoa	Vegetation	Miscellaneous
White crappie	12.0	72.8	0.5	7.0	0.0	1.7	6.0	0.0
Bluegill	21.5	40.5	8.5	12.0	0.5	10.5	6.0	0.5
Green sunfish	28.0	9.0	8.0	49.0	0.0	0.0	5.8	0.2
Redear sunfish	0.0	12.0	12.5	16.0	54.0	2.0	3.5	0.0
Longear sunfish	0.0	57.0	21.0	0.0	0.0	22.0	0.0	0.0
Largemouth bass	33.2	0.8	3.0	63.0	0.0	0.0	0.0	0.0
Black crappie	73.0	27.0	0.0	0.0	0.0	0.0	0.0	0.0

* Expressed in percent of total volume

TABLE XII

ITEMS* CONSUMED BY BOOMER LAKE FISHES (EXCLUDING HEXAGENIA SP.)

Species	Fish Remains	Aquatic Insects	Terrestrial Insects	Crustacea	Mollusca	Bryozoa	Vegetation	Miscellaneous
White crappie	8.2	29.0	0.9	6.4	0.0	0.5	5.4	0.0
Bluegill	1.8	37.8	10.0	1.3	0.2	22.7	27.0	0.0
Green sunfish	4.0	4.0	4.0	12.0	0.0	0.0	8.1	1.2
Redear sunfish	0.0	28.7	4.8	0.5	23.9	9.6	5.9	0.0
Longear sunfish	0.0	100.0	25.0	0.0	0.0	25.0	0.0	0.0
Largemouth bass	9.4	0.0	6.3	18.8	0.0	0.0	0.0	0.0
Black crappie	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

* Expressed in percent occurrence

TABLE XIII

"FORAGE RATIOS" OF BOOMER LAKE FISHES ON *HEXAGENIA* SP.

	SPECIES	PERCENT IN BENTHIC SAMPLES	PERCENT IN STOMACHS	"FORAGE RATIO"
1966				
June	white crappie	59	40	0.67
	bluegill	59	40	0.67
	redear	59	33	0.56
July	white crappie	44	71	1.61
	bluegill	44	50	1.13
	redear	44	46	1.04
August	white crappie	27	100	3.70
	bluegill	27	70	2.59
	redear	27	43	1.58
September	white crappie	24	100	4.16
	bluegill	24	19	0.79
	redear	24	25	1.04
October	white crappie	36	100	2.77
	bluegill	36	5	0.14
	redear	36	9	0.25
November	white crappie	54	100	1.85
	bluegill	54	6	0.11
December	white crappie	60	93	1.55
1967				
January	white crappie	55	74	1.34
February	white crappie	53	70	1.32
March	white crappie	61	100	1.64
	black crappie	61	50	0.82
April	white crappie	55	94	1.70
	largemouth bass	55	33	0.60
May	white crappie	61	90	0.48

TABLE XVI

MONTHLY CONTRIBUTION* OF SEVEN GROUPS TO THE TOTAL BENTHIC POPULATION

months	Hexagenia	Tendipedidae	Chaoborus	Branchiura	Caenis	Hyalella	Sialis
1966							
June	58.58	24.53	0.84	4.54	3.29	6.01	1.63
July	44.04	26.05	1.89	7.47	8.22	2.58	4.92
August	27.00	24.84	6.49	17.35	12.32	2.00	6.38
September	23.54	26.70	23.29	9.96	4.06	5.82	2.89
October	35.55	18.37	24.19	7.14	7.28	1.18	1.92
November	53.70	19.57	15.21	4.65	3.49	0.60	0.81
December	60.41	19.40	12.58	2.15	3.18	0.09	1.11
1967							
January	55.24	20.84	4.79	4.70	4.77	1.93	0.56
February	52.59	24.12	5.75	2.79	4.64	6.92	0.81
March	60.65	21.08	5.98	0.00	4.86	3.81	0.92
April	54.78	31.47	7.17	0.95	3.15	0.72	0.66
May	61.32	23.53	3.88	1.95	6.01	0.63	1.46

* Expressed in percent of total

Figure 1. Map of Boomer Lake and Drainage Basin

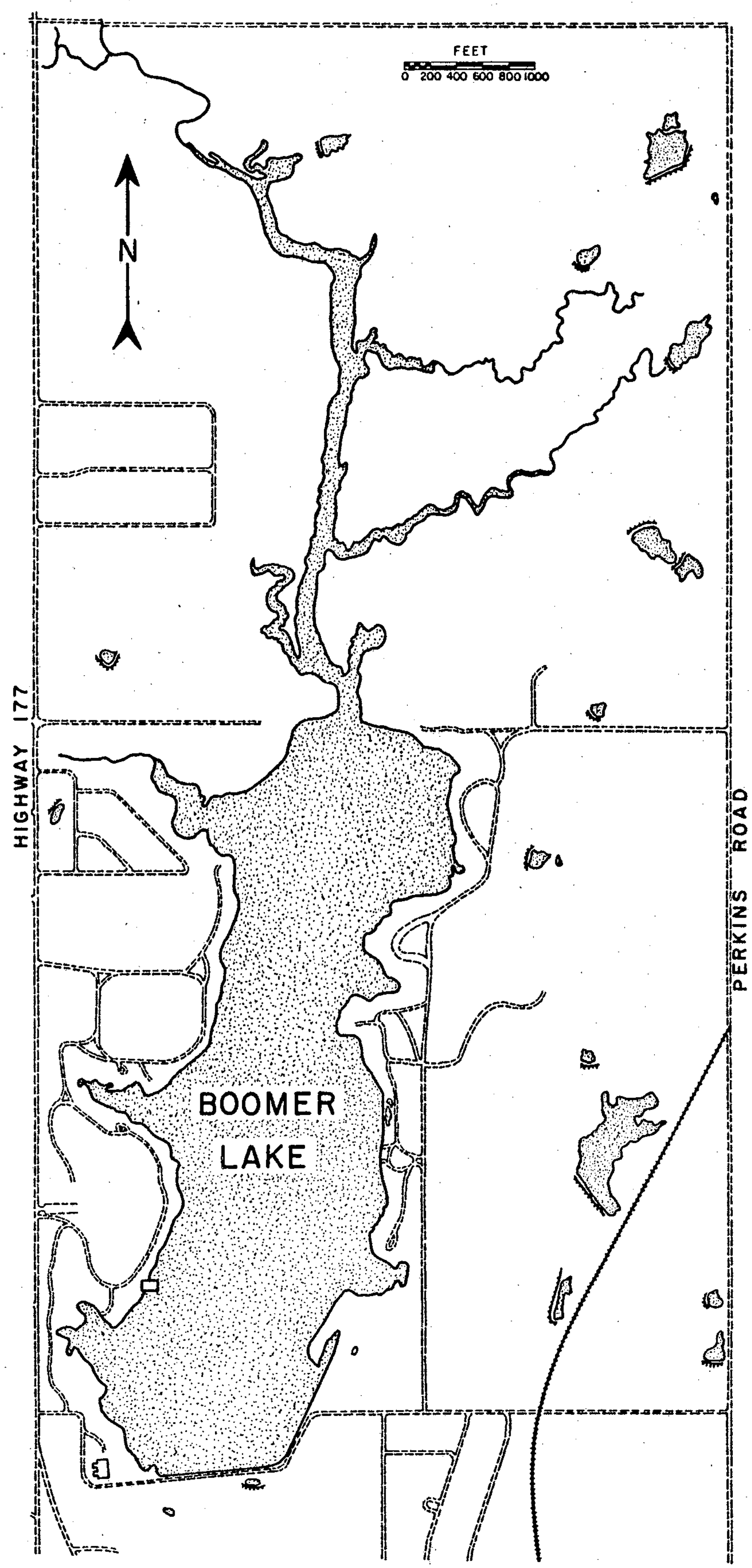

FEET
0 200 400 600 800 1000
N
HIGHWAY 177
PERKINS ROAD
BOOMER
LAKE

Figure 2. Map of Boomer Lake with Depth Contours, Transects for Siltation Survey, and Exclosure Placement

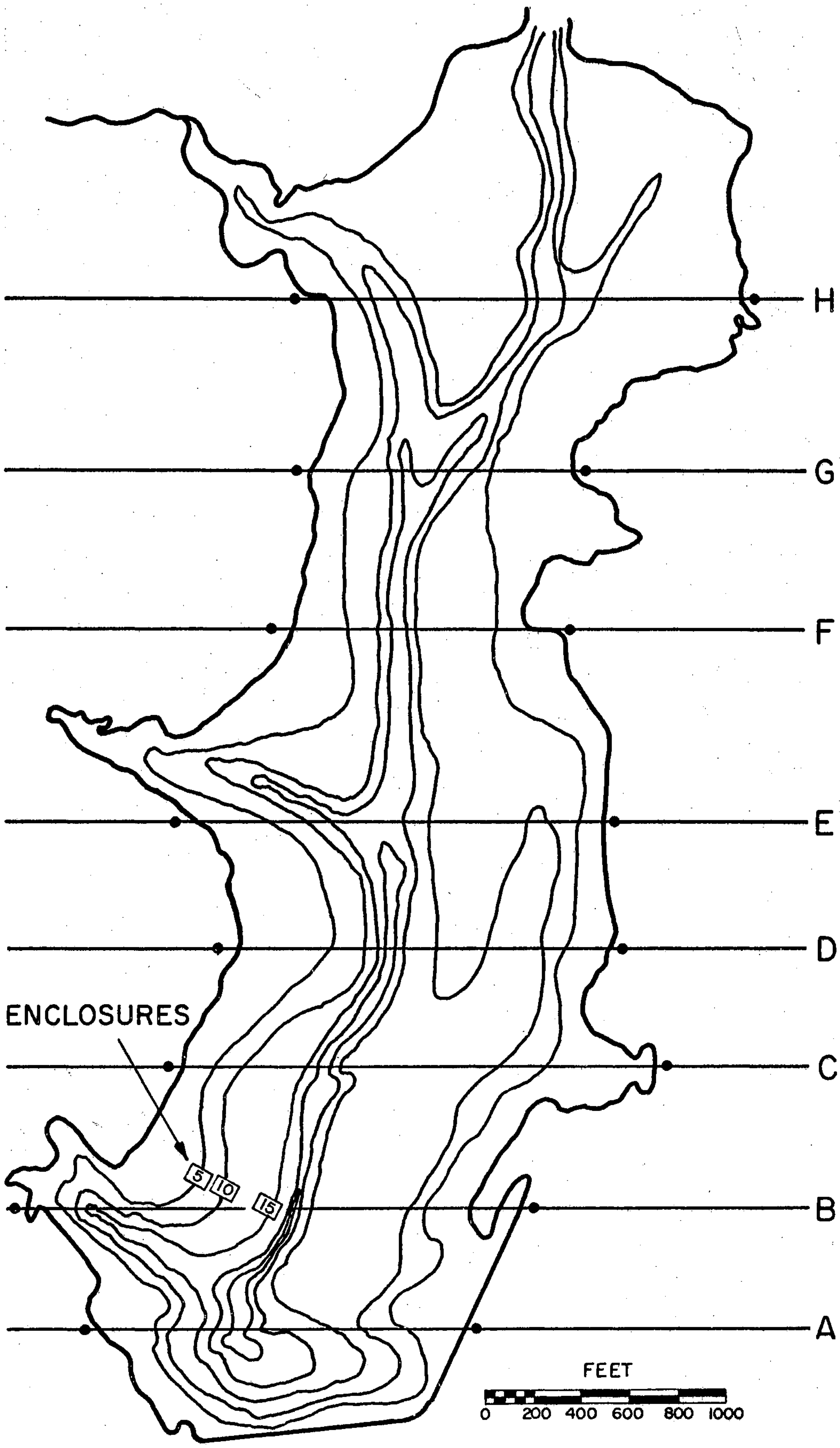
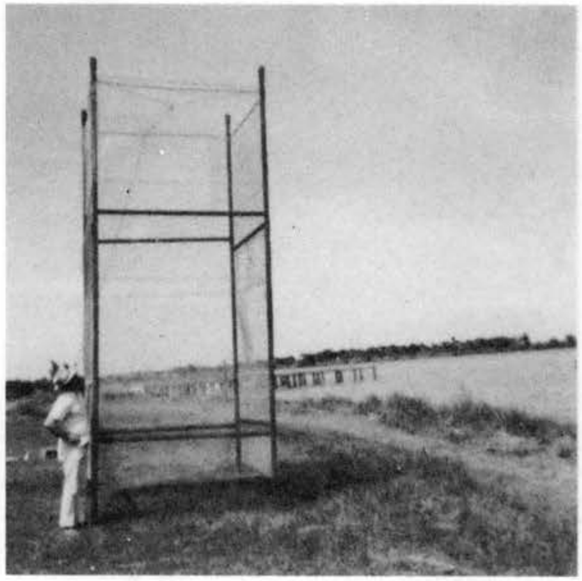

H
G
F
E
D
ENCLOSURES
C
5
10
15
B
A
FEET
0 200 400 600 800 1000

Figure 3. Exclosure - (a) General Appearance and Relative Size of the 15-ft Exclosure, and (b) 5- and 10-ft Exclosures in Place



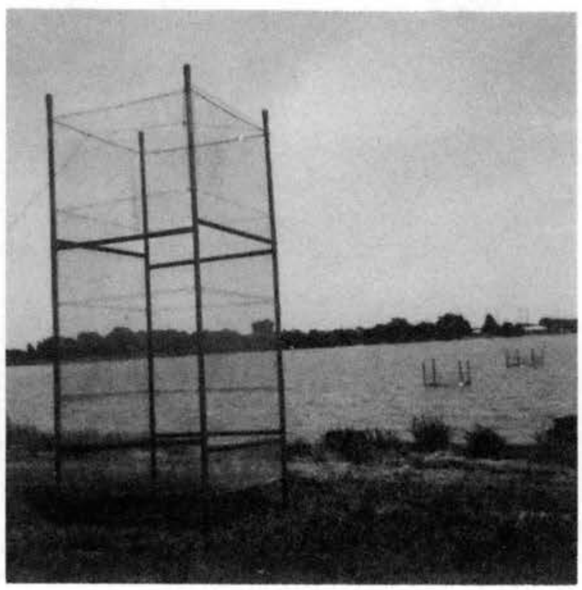


Figure 4. Siltation Profiles in Boomer Lake

legend:

solid line -- 1925

dotted line -- 1966

For transect locations A - H see Figure 2.

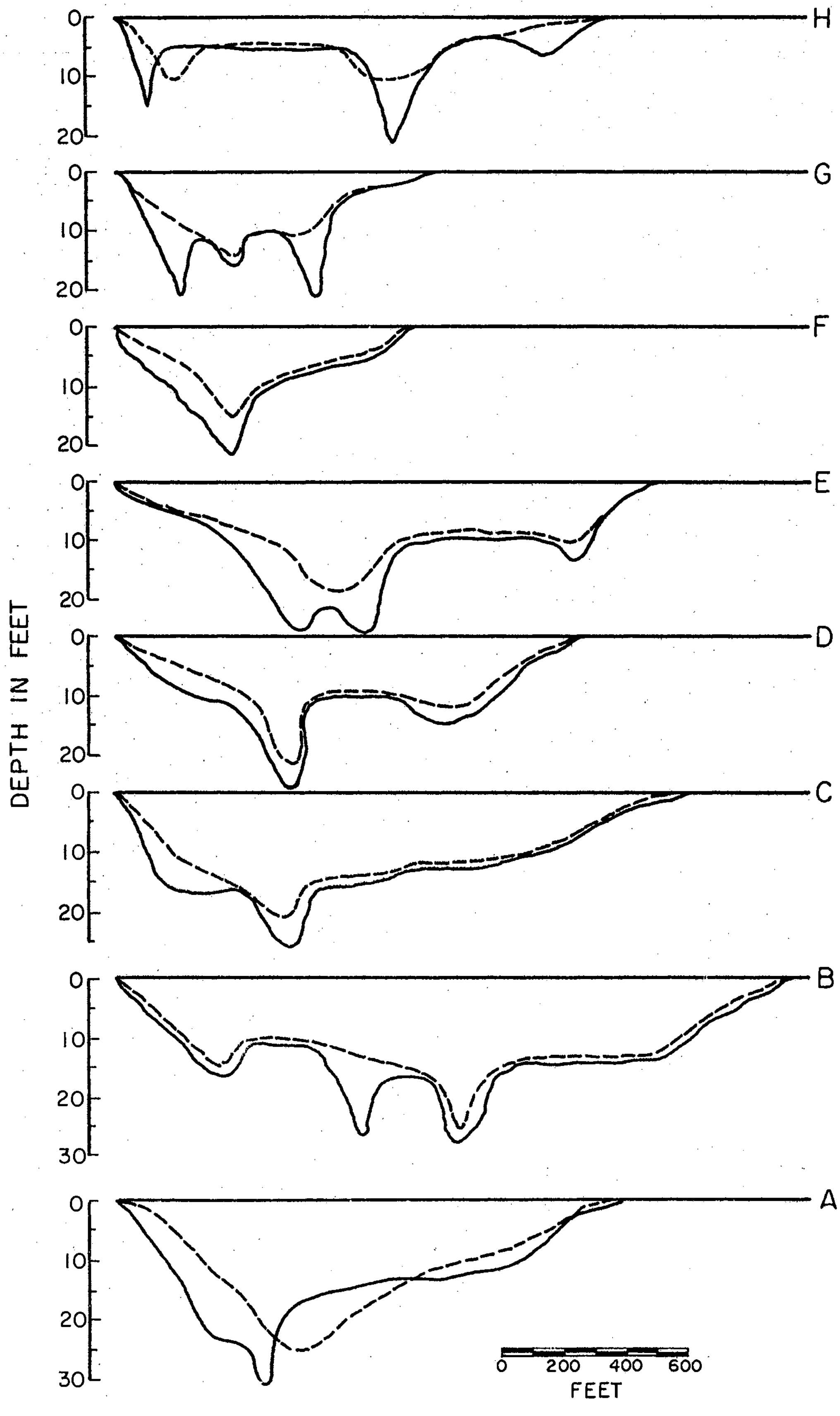

H
G
F
E
D
C
B
A
DEPTH IN FEET
0
10
20
30
0 200 400 600
FEET

Figure 5. Sampling Apparatus - (A) Boom Construction, (B) Exclosure Sampling, (C) Patterns for Successive Samples and (D) Control Area Sampling.

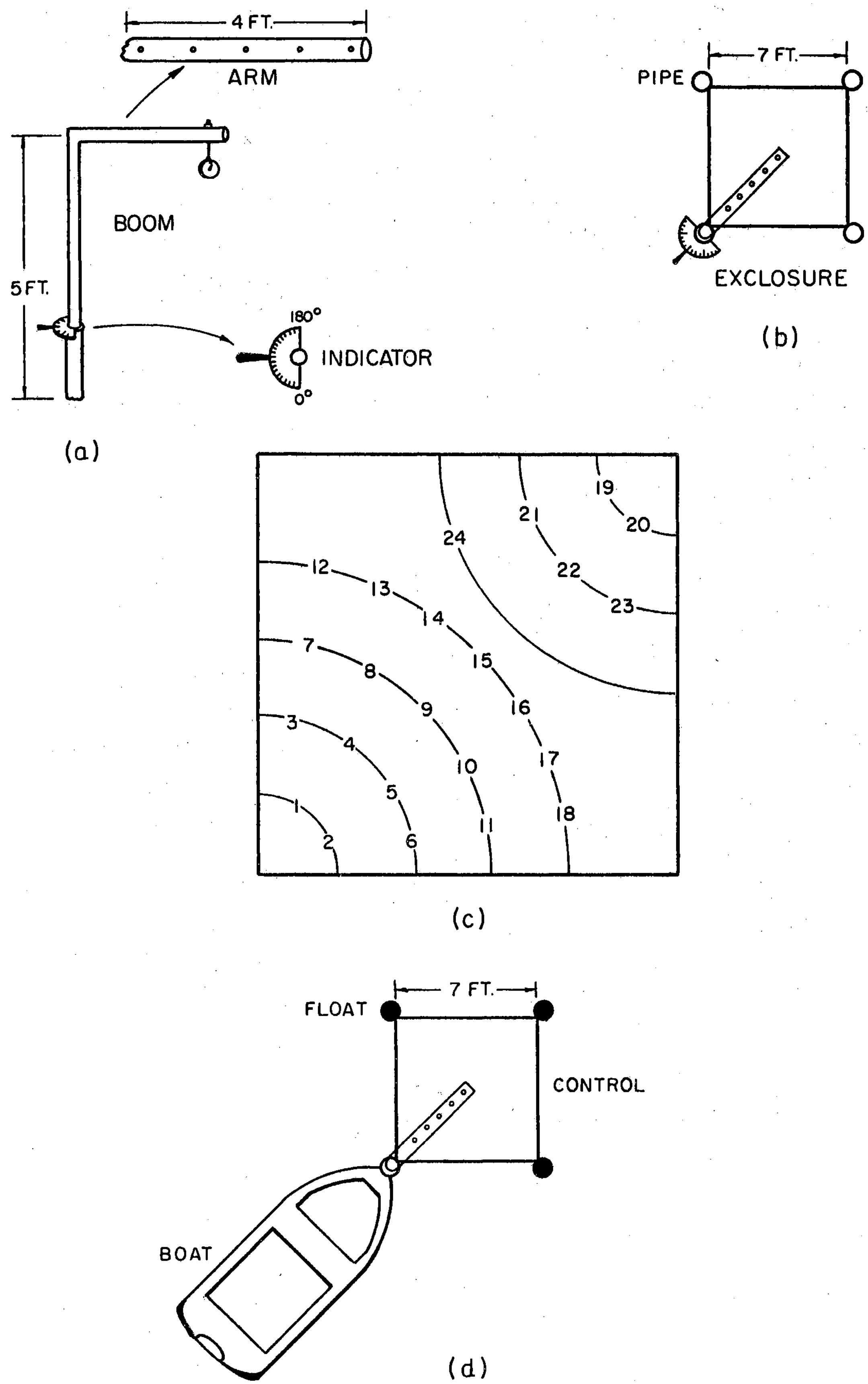
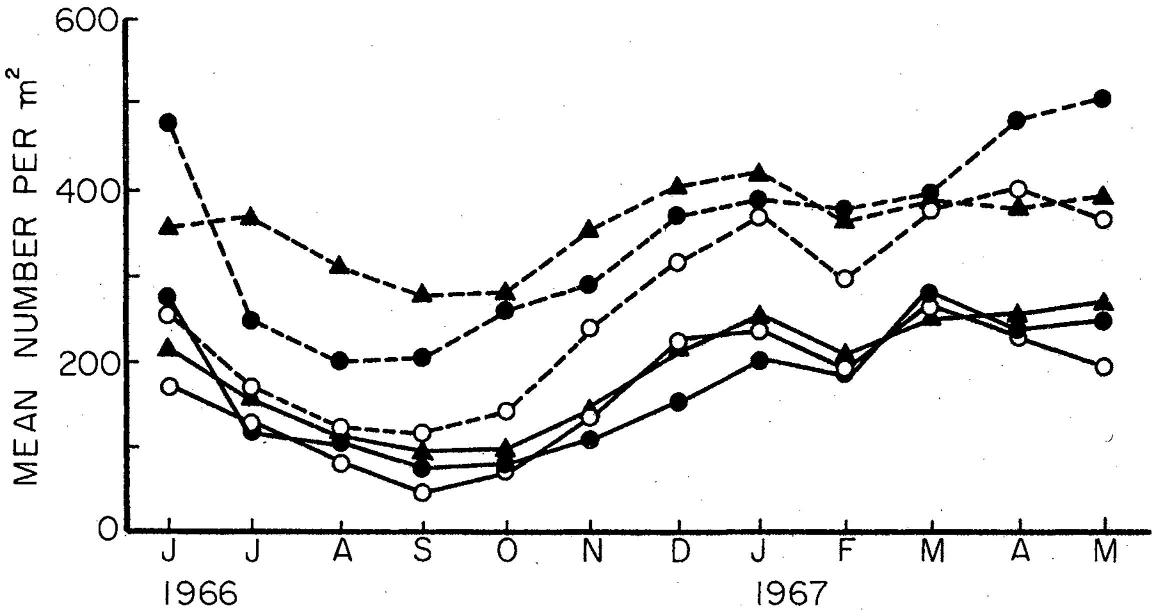

4 FT.
ARM
BOOM
5 FT.
180°
INDICATOR
0°
(a)
7 FT.
PIPE
EXCLOSURE
(b)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
(c)
7 FT.
FLOAT
CONTROL
BOAT
(d)

Figure 6. Estimated Mean Number of *Hexagenia* sp.

Exclosures	Dotted line
Control areas	Solid line
5-ft area	Open circle
10-ft area	Shaded triangle
15-ft area	Shaded circle



(6)

Figure 7. Estimated Mean Number and Biomass (dry wt) of *Hexagenia* sp. in the 5-ft Sample Areas

Figure 8. Estimated Mean Number and Biomass (dry wt) of *Hexagenia* sp. in the 10-ft Sample Areas

Figure 9. Estimated Mean Number and Biomass (dry wt) of *Hexagenia* sp. in the 15-ft Sample Areas

Legend for Figures 7, 8, and 9.

Exclosures ------------- Dotted line

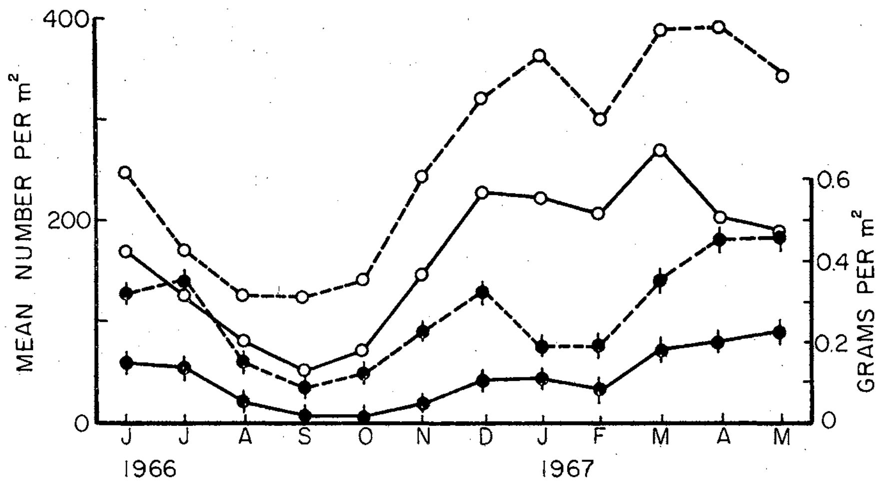
Control areas ---------- Solid line

5-ft area -------------- Open circle

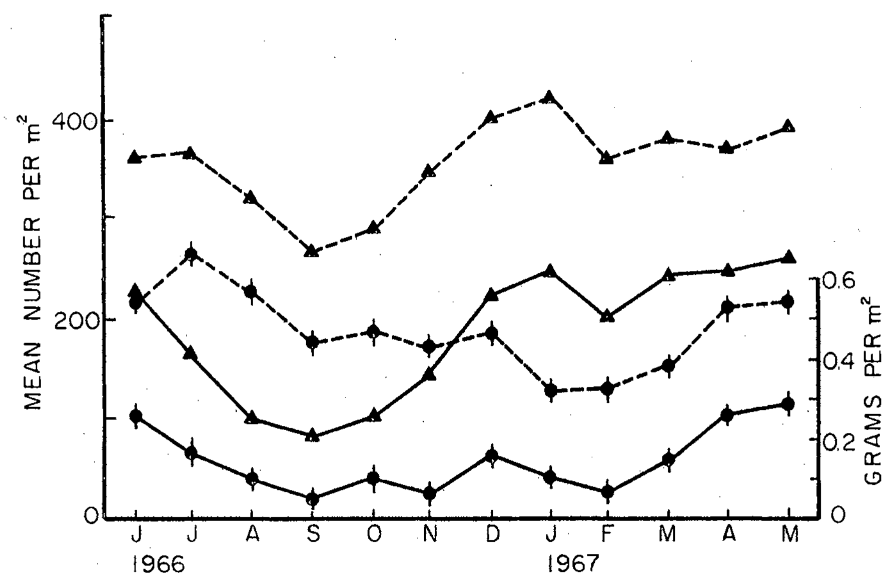
10-ft area ------------- Shaded triangle

15-ft area ------------- Shaded circle

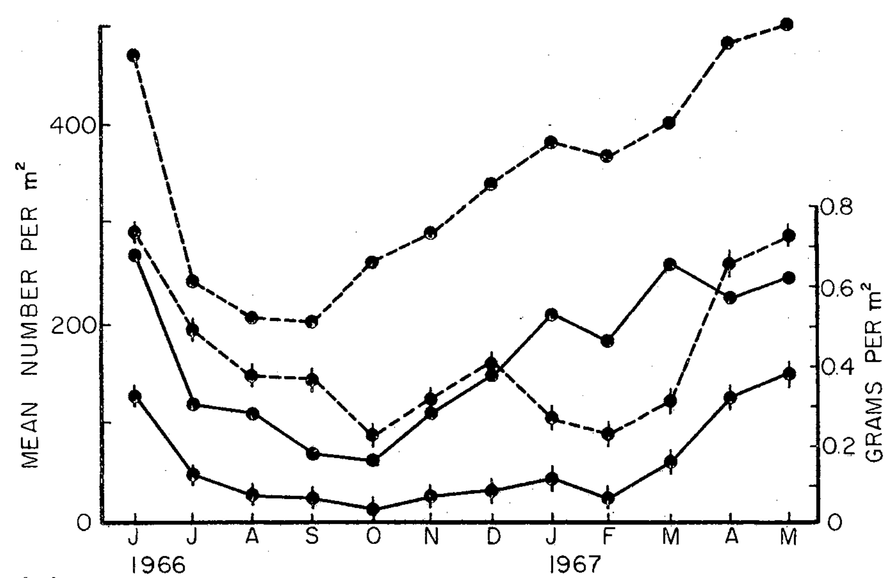
Biomass ---------------- Double-barred shaded circle


400
200
0
MEAN NUMBER PER m²
0.6
0.4
0.2
0
GRAMS PER m²
J J A S O N D J F M A M
1966
1967

(7)


400
200
0
MEAN NUMBER PER m²
0.6
0.4
0.2
0
GRAMS PER m²
J J A S O N D J F M A M
1966
1967

(8)


400
200
0
MEAN NUMBER PER m²
0.8
0.6
0.4
0.2
0
GRAMS PER m²
J J A S O N D J F M A M
1966
1967

(9)

Figure 10. Estimated Combined (exclosure and control areas) Mean Numbers of *Hexagenia* sp. Adjusted for Depth and Month Effects

5-ft area ------------------ Open circle

10-ft area ------------------ Shaded triangle

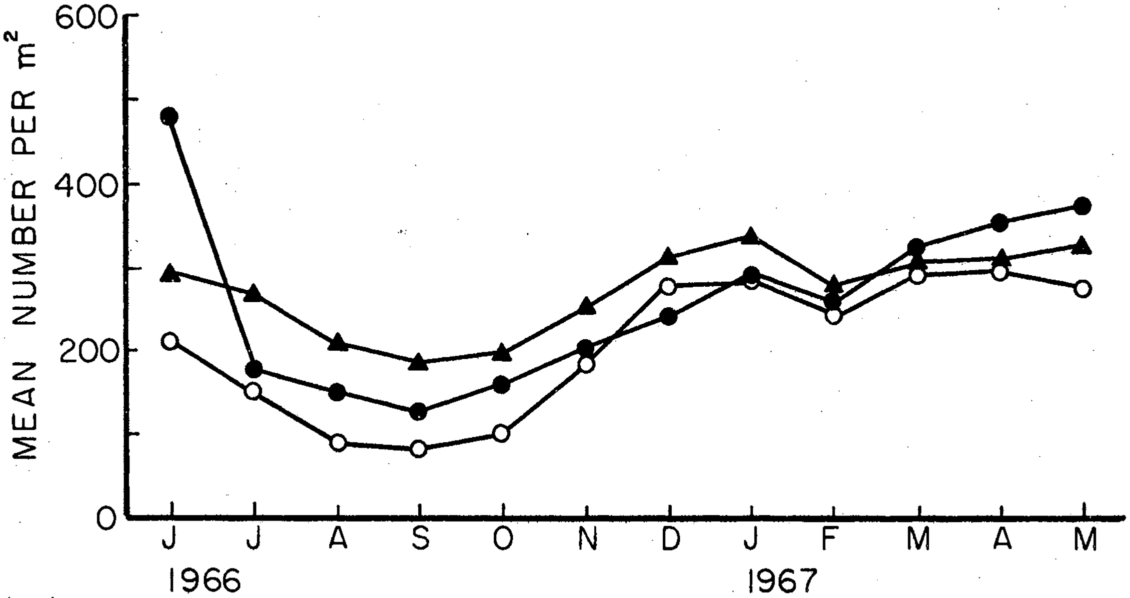
15-ft area ------------------ Shaded circle

Figure 11. Estimated Combined (all exclosure and control areas) Mean Numbers of *Hexagenia* sp. Adjusted for Treatment and Month Effects

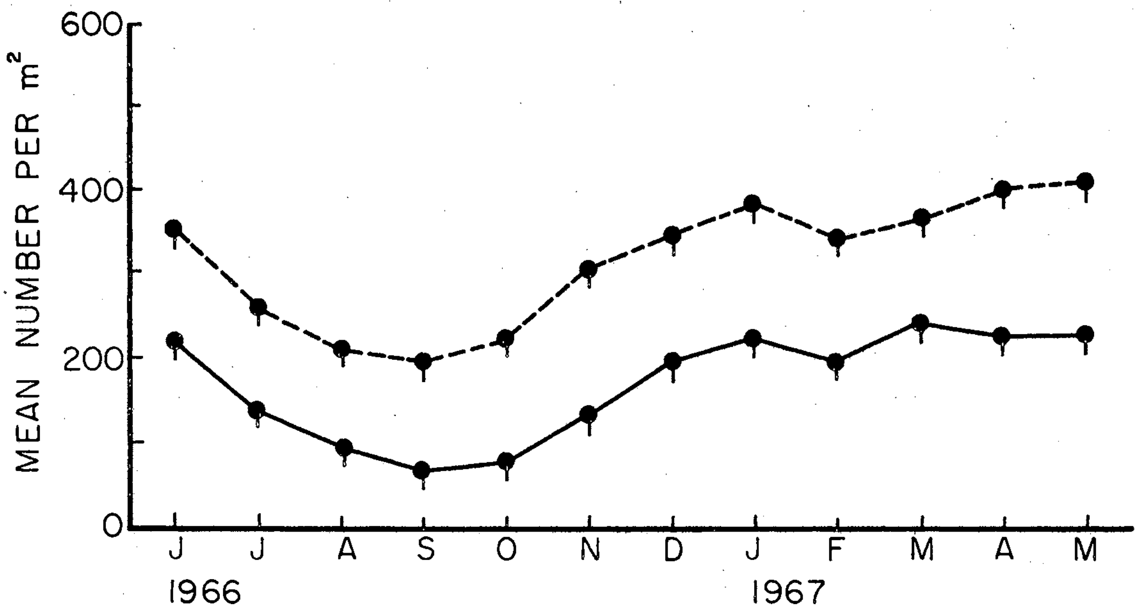
Exclosure areas ------------- Dotted line

Control areas --------------- Solid line

Population------------------- Single-barred shaded circle


600
400
200
0
MEAN NUMBER PER m²
J
J
A
S
O
N
D
J
F
M
A
M
1966
1967

(10)


600
400
200
0
MEAN NUMBER PER m²
J
J
A
S
O
N
D
J
F
M
A
M
1966
1967

(11)

Figure 12. Estimated Mean Monthly Biomass (dry wt) Adjusted for Combined Depth and Treatment Effects

Exclosure ------------- Dotted line

Control area ---------- Solid Line

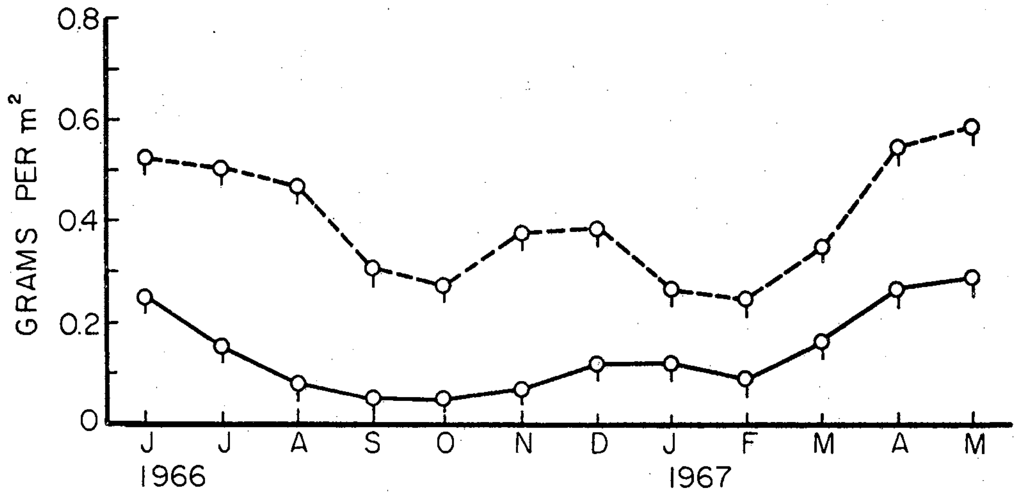
Figure 13. Estimated Mean Monthly Biomass (dry wt) Adjusted for Combined Treatment Effects for All Sample Depths

5-ft ------------------ Open circle

10-ft ----------------- Shaded triangle

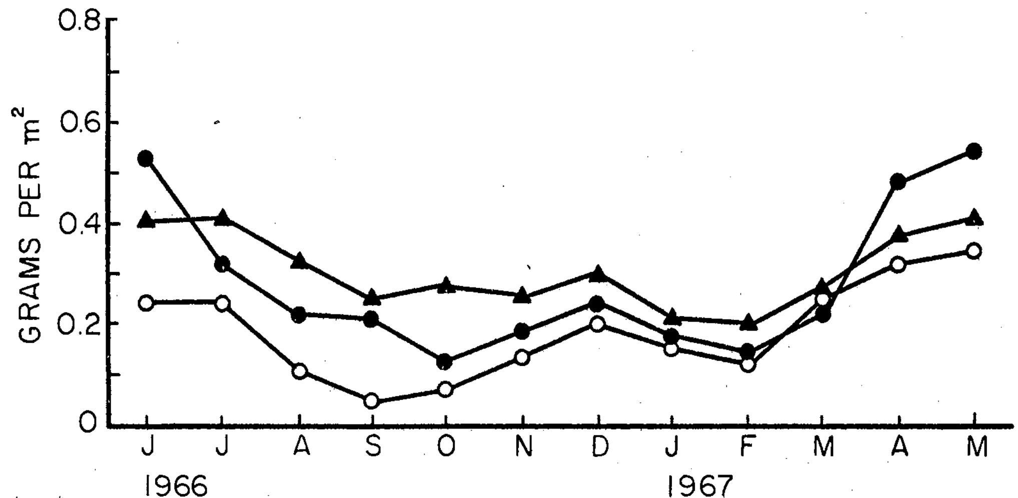
15-ft ----------------- Shaded circle

Figure 14. Estimated Mean Monthly Dry Weight for Individual Mayflies in Combined Sample Areas and Depths



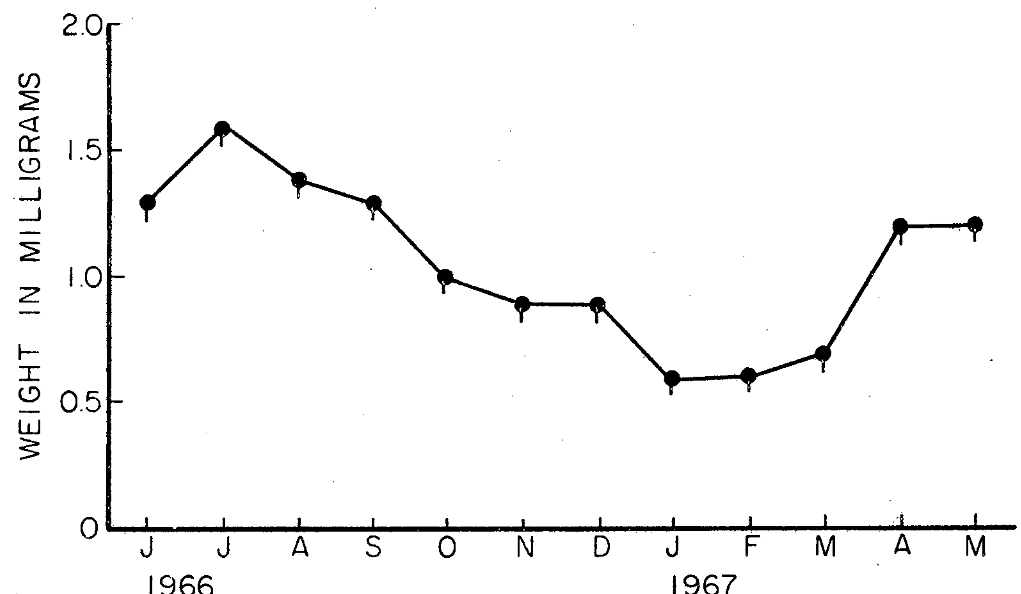
0.8
0.6
0.4
0.2
0
GRAMS PER m^2
J J A S O N D J F M A M
1966
1967

(12)



0.8
0.6
0.4
0.2
0
GRAMS PER m^2
J J A S O N D J F M A M
1966
1967

(13)



2.0
1.5
1.0
0.5
0
WEIGHT IN MILLIGRAMS
J J A S O N D J F M A M
1966
1967

(14)

Figure 15. Estimated Mean Monthly Dry Weight per Nymph from the 5-ft Sample Areas

Figure 16. Estimated Mean Monthly Dry Weight per Nymph from the 10-ft Sample Areas

Figure 17. Estimated Mean Monthly Dry Weight per Nymph from the 15-ft Sample Areas

Legend for Figures 15, 16, and 17

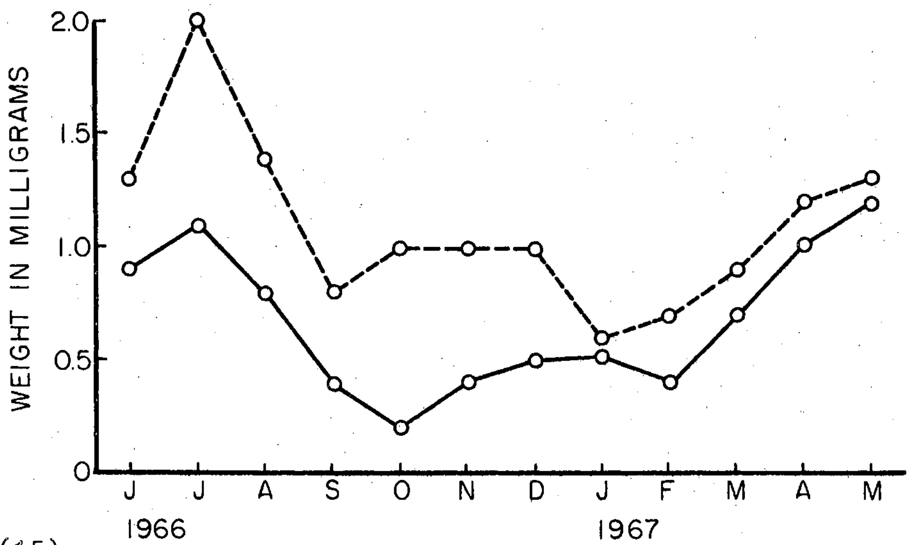
Exclosures ----------------- Dotted line

Control areas -------------- Solid line

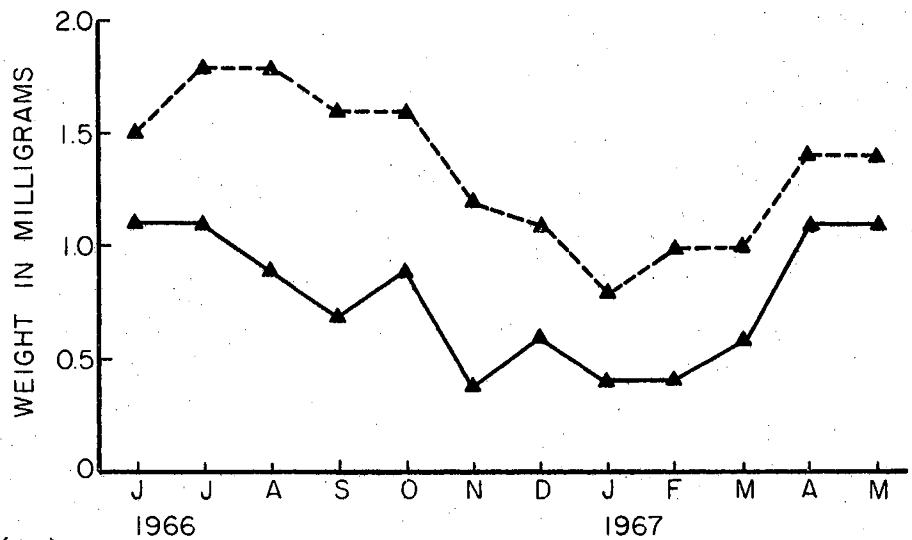
5-ft areas ----------------- Open circle

10-ft areas ---------------- Shaded triangle

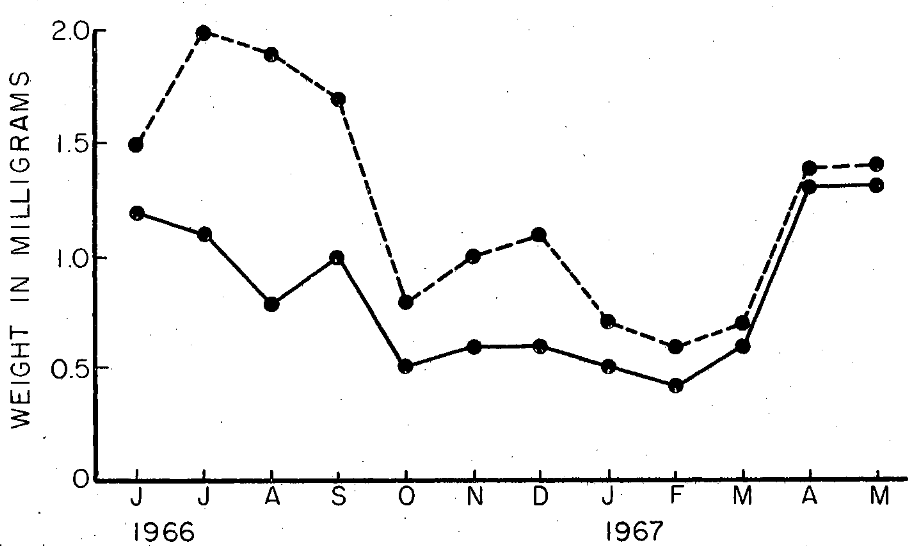
15-ft areas ---------------- Shaded circle


2.0
1.5
1.0
0.5
0
WEIGHT IN MILLIGRAMS
J J A S O N D J F M A M
1966
1967

(15)


2.0
1.5
1.0
0.5
0
WEIGHT IN MILLIGRAMS
J J A S O N D J F M A M
1966
1967

(16)


2.0
1.5
1.0
0.5
0
WEIGHT IN MILLIGRAMS
J J A S O N D J F M A M
1966
1967

(17)

Figure 18. Contribution of Three Nymph Sizes to the Mayfly Populations in the 5-ft Areas

Figure 19. Contribution of Three Nymph Sizes to the Mayfly Populations in the 10-ft Areas

Figure 20. Contribution of Three Nymph Sizes to the Mayfly Populations in the 15-ft Areas

Legend to Figures 18, 19, and 20

Exclosures ------------- Dotted line

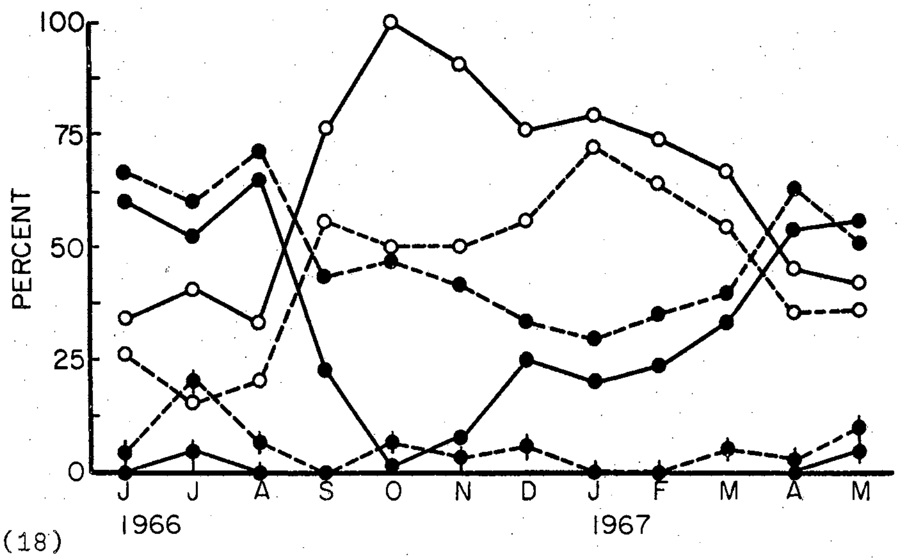
Control areas ---------- Solid line

Head capsule size in mm

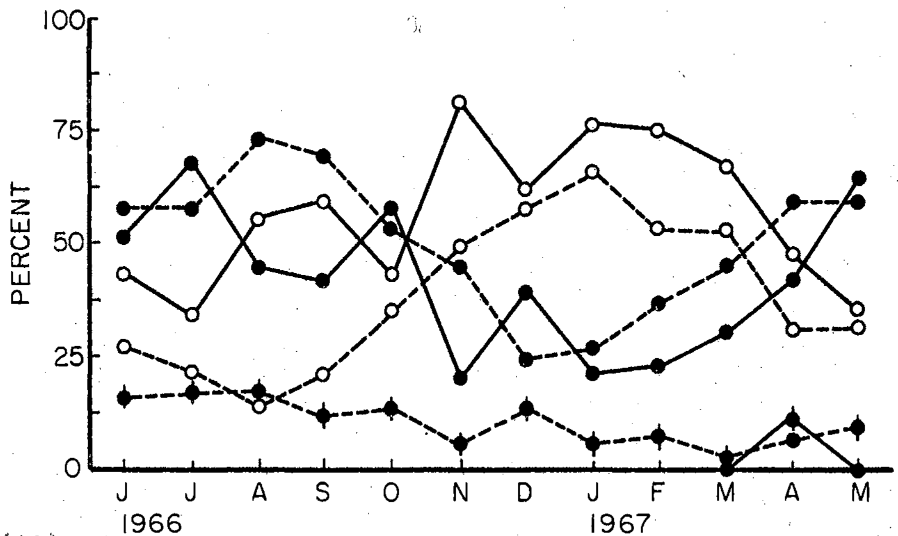
0.1 - 1.0 -------------- Open circle

1.1 - 2.0 -------------- Shaded circle

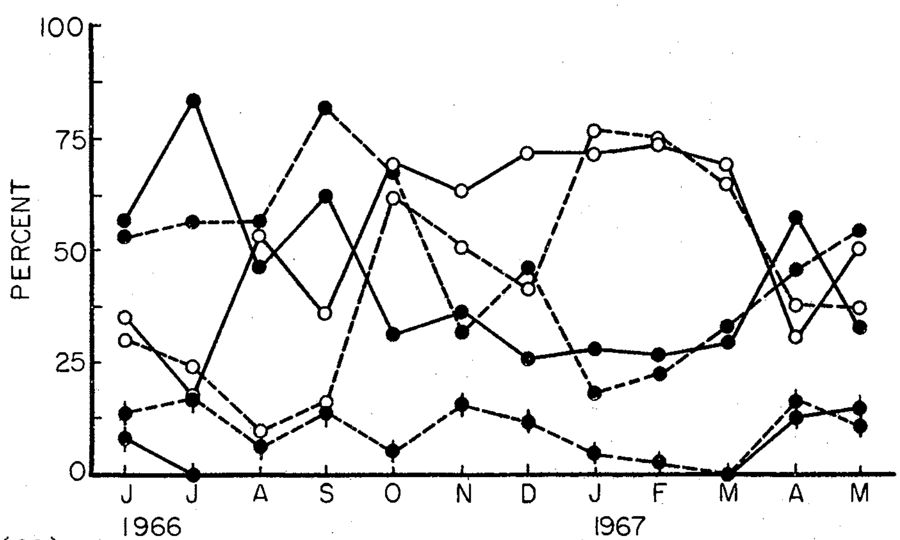
2.1 - 3.0 -------------- Double-barred shaded circle


100
75
50
25
0
PERCENT
J
J
A
S
O
N
D
J
F
M
A
M
1966
1967

(18)


100
75
50
25
0
PERCENT
J
J
A
S
O
N
D
J
F
M
A
M
1966
1967

(19)


100
75
50
25
0
PERCENT
J
J
A
S
O
N
D
J
F
M
A
M
1966
1967

(20)

APPENDIX B

APPENDIX B

ASSOCIATED BENTHIC MACROINVERTEBRATES

The various benthic invertebrates were treated in phylogenetic sequence and individuals are, where possible, identified to species. Thirty taxa were reported from Boomer Lake by Craven, (1968). The seven taxa of primary interest in this study were *Chaoborus puctipennis*, *Caenis* sp., *Sialis* sp., *Hexagenia* sp., *Hyalella azeteca*, *Branchiura sowerbyi*, and Tendipedidae. The distribution and abundance for these seven taxa were studied during a 12-month period (June, 1966, through May, 1967). Seasonal abundance is given for exclosures and control areas at three depths.

Siltation in bodies of water, both lentic and lotic, has been shown to reduce microhabitats (Harrel, 1966), to be detrimental to insects living on plants (McGaha, 1952), and result in a reduction in populations of gastropods and pelecypods (Paloumpis and Starret, 1960). The reduction in Boomer Lake of suitable habitats as a result of siltation probably caused reductions of many benthic groups.

Oligochaetes of Boomer Lake were widely distributed and varied in abundance. The primary concentration of Oligochaetes appeared to be in the 0- to 10- ft depths, and they were, for the most part, much more abundant inside than outside the exclosures. However, they were more numerous outside than inside at the 10-ft depth during March and April and at the 15-ft depth during June, July, November and May. The absence of Oligochaetes in the samples at the 15-ft depths from November through April is not explained.

The population of Branchiura sowerbyi comprised less than 20% of the total benthic population throughout the sampling period and less than 10% for 10 months (Table XIV).

Hyalella azteca (Saussure) abundant in vegetated areas comprised less than 7% of the total benthic group throughout the sampling period (Table XIV). According to Mackin (1941), H. azteca was abundant in vegetated areas throughout Oklahoma in clear permanent ponds. Buscemi (1961) also found H. azteca associated with vegetation in shallow situations in Parvin Lake, Colorado.

Hexagenia sp. is discussed in Chapter IV.

Caenis sp. was most abundant in January and February, in agreement with Sublette (1953 and 1957) for Lake Texoma.

Sialis sp. varied considerably in abundance during the sampling period and was not used extensively by fishes. The maximum number ($362.7/m^2$) of individuals appeared in July, 1966. Harrel (1966) also found a peak abundance in July.

Chaoborus punctipennis (Say) populations were highest in October and lowest in August, in agreement with Buscemi (1961). The summer populations of this species were heavily utilized by bluegill and white crappie. C. punctipennis comprised only a small part of the total biomass because of their small size. Stahl (1966) reported that older larvae tend to be benthic in the light periods and to have nocturnal vertical migrations, the young tending to be planktonic. The maximum numbers of Chaoborus sp. of Boomer Lake appeared to be in the deeper water. Dorris (1956) attributed a midwinter decline of C. punctipennis in the Mississippi River to mortality. *Chaoborus* sp. in Boomer Lake apparently has a 1-year cycle (Craven, 1968).

Tendipedidae - Members of this group were not identified beyond the family unit. The decline in the population during the summer months was due primarily to emergence, and the increase during the fall months to recruitment. Craven (1968) reported that the depth and bottom temperature did not account for variation in numbers of the Boomer Lake population.

VITA

William Frank Wade

Candidate for the Degree of

Doctor of Philosophy

Thesis: ECOLOGY OF HEXAGENIA SP. AS INFLUENCED BY CENTRARCHID PREDATION

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Professional Experience: Researcher for Ozark-Mahoning Chemical Company at the University of Oklahoma Biological Station, Willis, Oklahoma, Summer, 1961; Trainee fellowship, State Game and Fish Department, Norman, Oklahoma, 1961-1962; Graduate Teaching Assistant, University of Oklahoma, 1962-1963; Graduate Teaching Assistant, University of Oklahoma Biological Station, Willis, Oklahoma, Summer, 1963; Oklahoma Biological Survey Assistant, 1963-1964; Graduate Teaching Assistant, Oklahoma State University, 1964-1967; Supervisor of City Lakes, Stillwater, Oklahoma, 1965-1968.

Member: Phi Sigma, American Fisheries Society, and Oklahoma Academy of Science.